ONDERZOEKSRAPPORT NR. 8402

A MICROCOMPUTER SYSTEM FOR MRP AND SCHEDULING IN ESSOCHEM

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Wettelijk Depot : D/1984/2376/2

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ABSTRACT

The purpose of this paper is to describe the design, the development and the implementation of an interactive microcomputer system that is being used as an operational and planning instrument in Essochem for the production of lube oil additives (under the "Paramins" trade-mark) at Vado Ligure in Italy. The system is called PRISMS which stands for : Paramins Reporting and Information System for MRP (Manufacturing Resource Planning) and Scheduling.

I. INTRODUCTION

The last decade a lot of attention has been paid to the design, development and implementation of production planning systems in the chemical industry (4), (5) and (7). This is due to inadequate inventory and production control procedures so far. Together with this renewed attention, the usage of microcomputers has grown exponentially from the late '70's to early '80's. Fast 16 bit machines have been introduced and mass storage cost has been reduced. Various production planning and scheduling software appeared on the microcomputer market but all these systems did not and do not yet address all aspects of Manufacturing Resource Planning (MRP) and Scheduling.
As a result, Essochem Europe Inc. decided to design and develop a system named PRISMS, which was to integrate MRP and Scheduling into one overall system (3), (6), (9). In many cases, the existing MRP systems are not oriented towards the decision aspects of controlling production, but are considered only as large scale database systems. The existing scheduling systems, on the other hand, are too specific and did not fit the Essochem production environment of lube oil additives (1), (9).

II. THE PRODUCTION ENVIRONMENT

In this section a description is given of the plant, the blending process and the reactor process.

1. Description of the plant:

   Essochem manufactures and markets a number of additives for oil products.

   The manufacturing process consists of two stages:

   (a) The reaction operation

   Raw materials, purchased either from affiliates or from outside suppliers are first reacted into intermediate products, which are called reactor products.

   (b) The blending operation

   Reactor products are blended, together with other purchased components called blend components, into finished goods, the blended products or blends.

   The plant produces about 60 different blends, from about 12 reactor products and about 25 blend components. The reactor products are manufactured on 3 types of reactors from about 20 raw materials.

   An overview diagram of the plant's blending and reaction operations is given in figure 1.
   The product structure of a typical blended product is illustrated in figure 2.

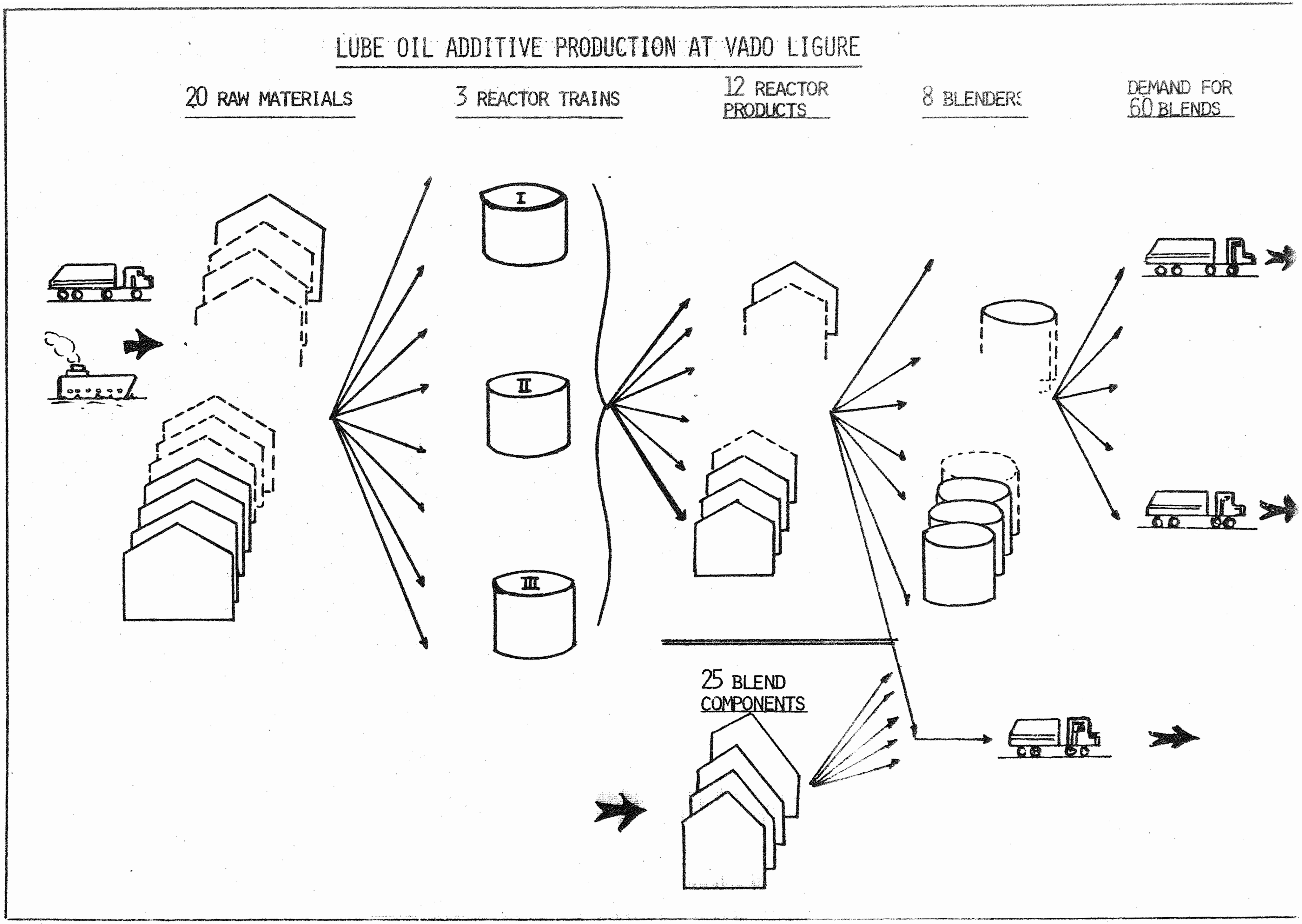
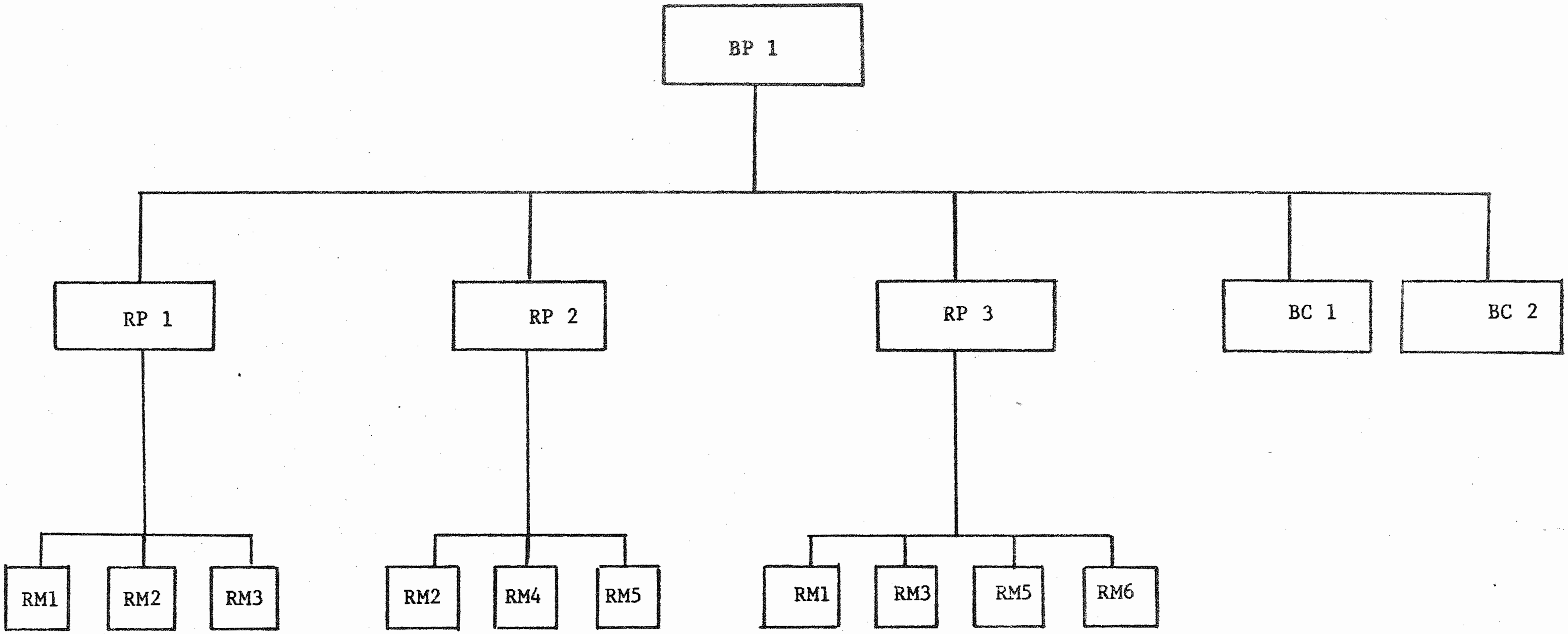


FIGURE 1 : PLANT DESCRIPTION



BP : Blended product
RP : Reactor product
RM : Raw material
BC : Blend component

Figure 2 : Example of a structure diagram for producing blended product BP1

The demand can be grouped as follows:

(a) Blended products are produced and delivered on order, i.e. no blended products are kept in inventory.

(b) Some blend components are purchased and resold directly and

(c) Some reactor products are not only used in the blending operation but also sold directly.

The blended products have an external demand, or in MRP-terms, an independent demand. The reactor products and the blend components partly have an internal demand, dependent on the requirements for the blended products, and partly an external demand. The raw materials have an internal or dependent demand since their demand is directly related to and derived from the demand for the reactor products.

The amount of reactor products and blend components required to meet a finished product demand is determined using the product structure (bill of material) for this particular blend. By also considering the manufacturing lead time for the blend, we can determine when these reactor products or blend components will be needed in order to meet the due date. This requirements calculation is referred to as deblend calculation.

Similarly, the dereact calculation determines the quantities and the timing of the raw material requirements, needed to meet a certain demand for reactor products.

The blender and reactor scheduling is part of a broader planning activity, which includes the following areas:

- Raw material and blend component delivery (preparation and storage of feeds)
- Order tracking
- Inventory follow-up
- Reaction processes (including filtration)
- Storage of reactor products
- Blending (loading, mixing, unloading) and customer pick-up.

Until PRISMS was installed, the planning and scheduling of operations were done manually. When computerizing the procedure, it was possible also to address other areas such as capacity planning and delivery follow-up.

2. The blending process description

The plant consists of 8 blenders with a partial interchangeability. Blender scheduling includes the scheduling of the appropriate blenders (which products on which blenders) and the sequencing of products on these blenders. While done manually, the planning was based on expected shipments over a 10-day horizon.

The main constraints involved in blend scheduling are:

(a) Blending is on order:

- No blends should be kept in inventory.
- Blending is started only when the finished product is scheduled for delivery a few days later.
- The blend schedule must reflect the time needed for the four steps of the blending process :
  - Charge the blender with the necessary components
  - Mix the products
  - Verify the quality
  - Load the trucks when the blend is finished

  In total, the whole process takes about 2 to 5 days.
- The blenders operate 7 days a week.

(b) Storage limitations of blend components:
The most important blend components are stored in a number of on-site tanks. Other components are stored in drums, either on-site or at external locations.

(c) Truck scheduling:
Truck scheduling is related to the blend scheduling and covers the transport of finished products (blends) and blend components to and from warehouses or affiliates. There are several types of penalties for not meeting the truck schedule, e.g. truck demurrage, overtime work (for loading truck), or lost production.

3. The reactor process description

There are three reactor lines, each producing a particular group of reactor products. The different reactor products are manufactured based on specific recipes. These reactor recipes (bills of material) may change over time to reflect new developments.

Some reactor processes consist of two stages, namely the reaction process and a filtration. The production lead time depends on the batch size. The reactor scheduling horizon is the same as for the blenders, 10 days.

III. THE PRISMS FRAMEWORK

1. Main functions

The main functions of PRISMS are summarized in figure 3, which also illustrates the meaning of the acronym. The information arrives like the colours of light, i.e. inseparable unless a prism is used to create the rainbow colours.

PRISMS is a framework for detailed weekly production scheduling and for monthly production planning, which requires a plant database including product master files, bills of material, inventory locations and blender as well as reactor descriptions. PRISMS also consists of a transaction system as well as a database for both order and inventory tracking, inventory projection, and material resource planning calculations.

The two main planning activities are the monthly plans and the daily/weekly schedules.

- Monthly planning

  On a monthly basis, PRISMS is used to provide a master schedule for the next three months based on forecast demand and target inventory levels. It provides a supply (raw materials and blend components) and demand (blended products and reactor products) balance by preparing monthly production plans for both blenders and reactors. This module also includes a deblend and dereact calculation creating monthly purchasing plans for raw materials and blend components. It also signals run-outs and projected inventory levels. This deterministic simulation system requires as input not only the blend plan but also the reactor plan. The computer program suggests schedules but they may be manually adjusted by the scheduler.

- <u>Daily/weekly scheduling</u>

  The scheduler can specify short-term plans for independent demand items (blends). The primary function is to use the lead time information and bill of material structures to explode the master plans into a time-phazed schedule for all reactor products and a time-phazed purchase plan for raw materials and blend components. The scheduling is based on registered orders. The deblend and dereact calculations yield an inventory projection for all intermediate products and raw materials. Most of the required information has to be updated daily (data on process units, feed availability, storage facilities, backlog of order, shipping plans, etc...)

The main challenge for the scheduler is the feasibility of the schedules. Examples of non-feasible schedules are: to schedule a blend requiring a component that will be out of stock when needed, to schedule production or raw material arrivals that will cause tankage overflow.
The system does not include an optimizer, but the scheduler can simulate different schedules or, in other words, use the system as a deterministic simulator (see section III.4).

One advantage of PRISMS is that the coordination between different departments is enhanced. Lack of coordination can create excess work-in-process inventories, too many set-ups, reduced throughput or inflated lead times.
The system helps the schedulers in all stages of the planning process by avoiding repetitive manual calculations. The system operates in an interactive mode (on-line) with daily input and output reports, it accepts input data in a format convenient for the user and the output reports are immediately usable for planning purposes.

PRISMS provides the user with a set of menus, commands and messages.

Menus inform the user of the opportunities open from that screen. All data requirements are entered by the user on defined screens. Internally, all data are arranged and saved in data files. The content of these files can then be displayed on the screen as tables or used for hard copy reports.
The user has the opportunity to adjust any data item and see the results of that adjustment displayed on the screen.
Because of the screen limits (24 lines x 80 characters) only a part of the data table can somehow be shown, which limitation is overcome by scrolling commands (Screen Manipulation).
Other commands are available such as the Case Manipulation and Action commands.

The bottom line of the screen is used for displaying messages for the user and as a command area for the user.
The messages describe on each screen which data should be entered by the user, which key should be pressed to ensure the continuation of the program, or draw the user's attention to invalid data input.

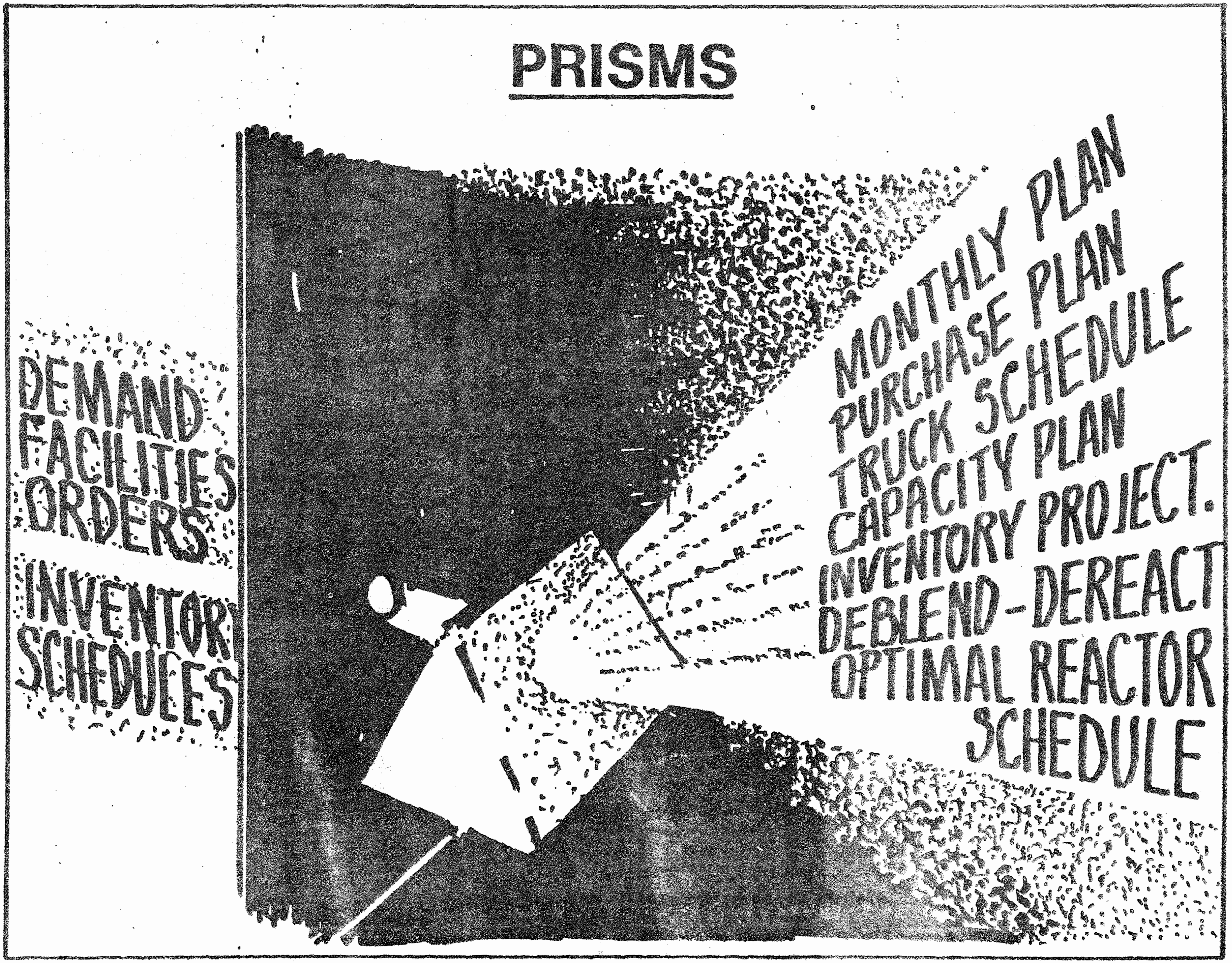


Figure 3 : The PRISMS main functions.

2. PRISMS as a modular system

The advantages of a modular system are straightforward :

- Modular systems are easier to design and develop.
- The different modules and subsystems can be tested separately facilitating debugging.
- Modular systems can easily be adapted to changing needs.
- Modular systems can easily be expanded.

The PRISMS system consists of the following modules:

- Plant description module.
- Order tracking module.
- Inventory tracking module.
- Monthly planning module.
- Daily/weekly scheduling module.
- Deblend/Dereact module.

Figures 4, 5, 6 and 7 illustrate the main functions and their interrelationships.

The plant description module (figure 4) enables the user to:

- Update the plant description data files, which constitute the framework in which all system calculations will take place, by adding, changing or deleting product descriptions, bills of materials, reactor line descriptions, etc...

- Inform about the actual contents of the plant description data files (soft copy on screen, hard copy via printer).

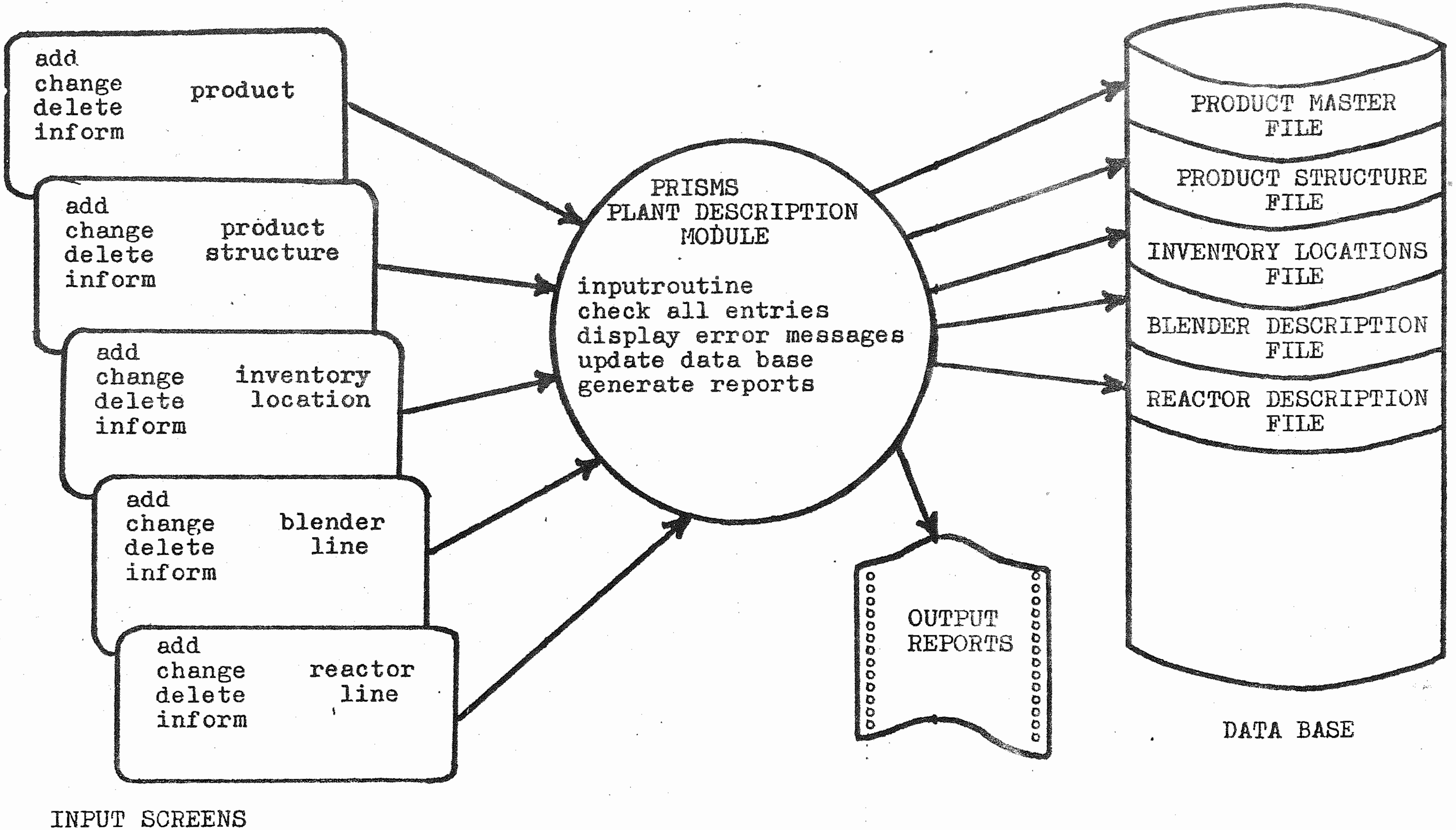


Figure 4 : The Plant Description Module

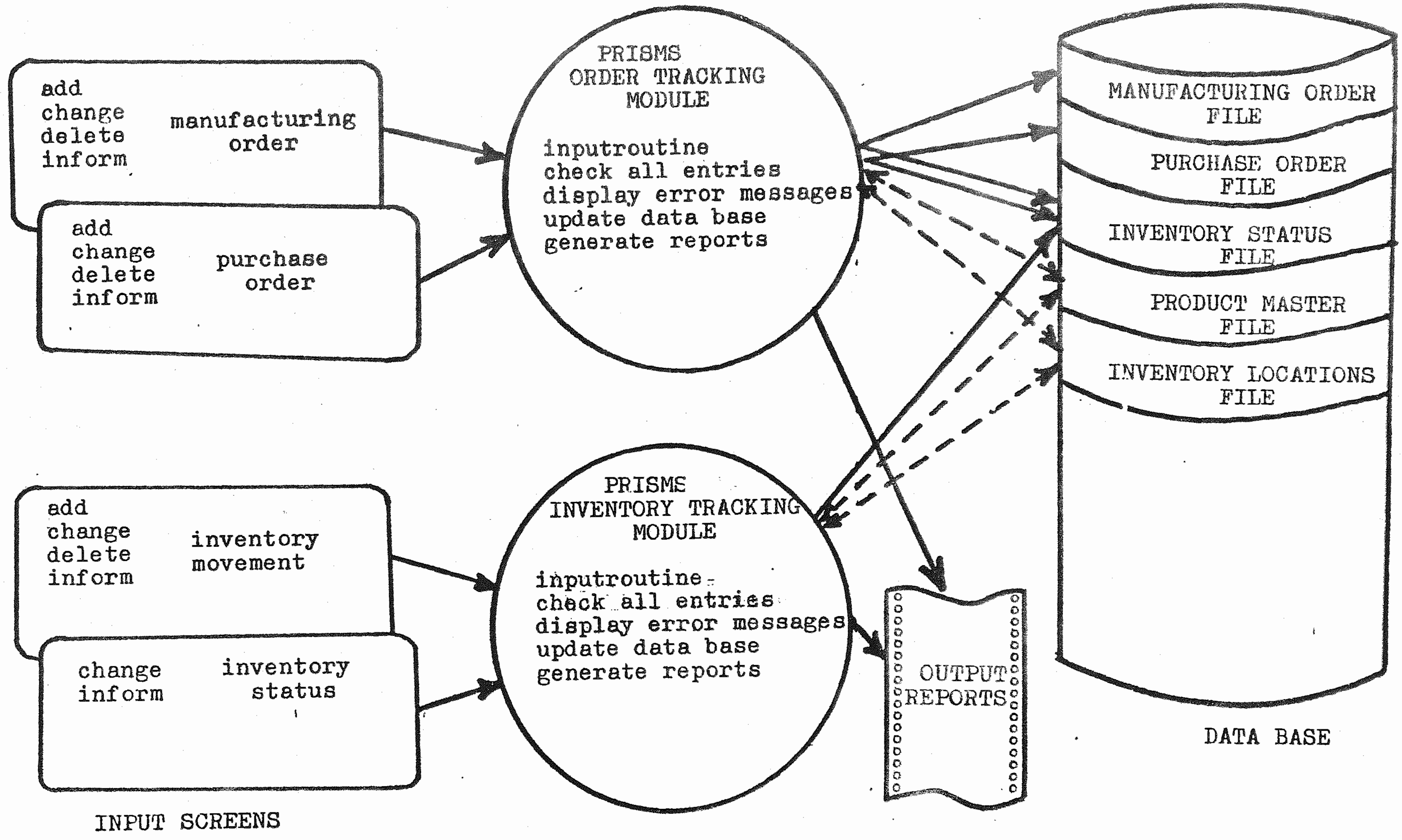


Figure 5 : The Order and Inventory Tracking Modules

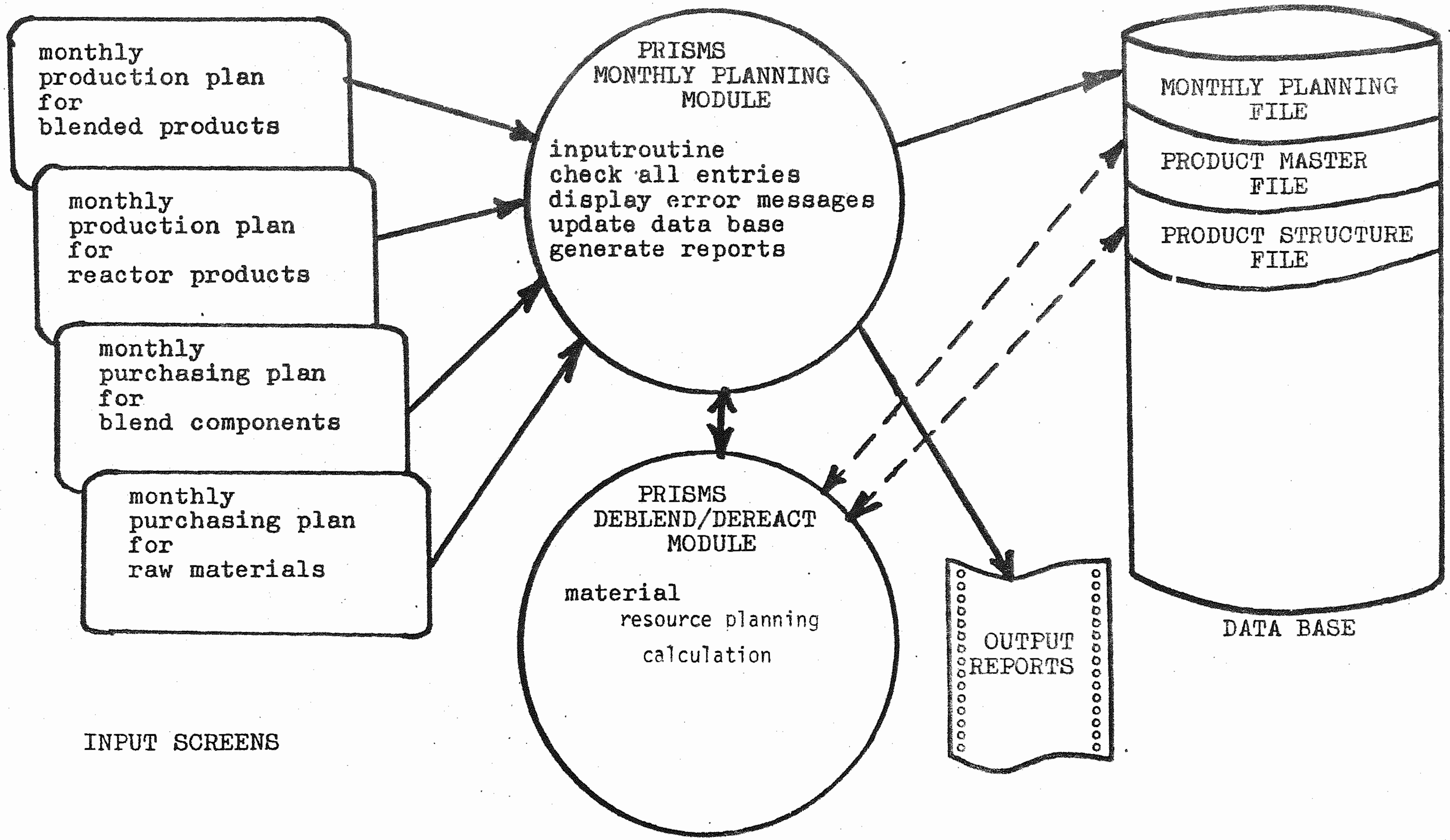


Figure 6 : Monthly Planning Module.

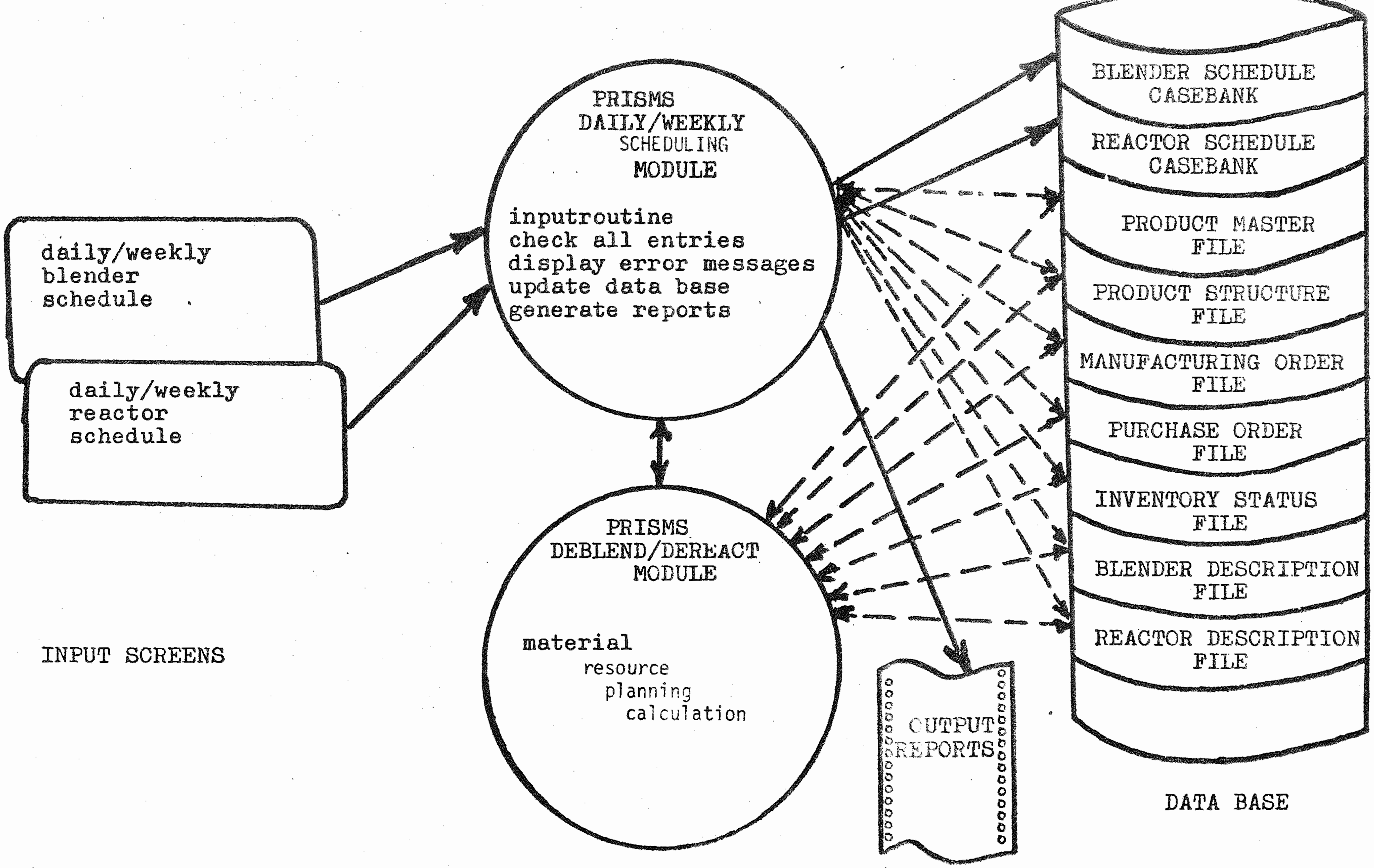


Figure 7 : The daily/weekly Scheduling Module

The plant description module controls the user's input via the input routine, protects the data file information against invalid user inputs by issuing error messages, updates the appropriate data files and generates the requested reports.

The order tracking and inventory tracking modules (figure 5) handle in a similar way all user input on order and inventory transactions. This requires some (dotted line) interaction between these modules and some of the plant description data files, as illustrated by the figure.

The monthly planning and daily/weekly scheduling modules supervise the user planning and scheduling input (figure 6 and 7). Both modules then interact with the deblend/dereact module (and all data base files) for the material resource planning calculations and the inventory projections.

3. Cost/Benefit analysis

The model has been developed in the period 1981-1983 in cooperation with the Department of Applied Economics, K.U. Leuven. Total development effort consists of 0.4 man year for Essochem analysts, and the student contribution which may be estimated at 1.3 man year.Costs to run and support the model are estimated to be less than 1 man month per year.

The benefits consist of reduced working capital (inventory reduction), truck demurrage and improved manpower utilization.

4. PRISMS and Manufacturing Resource Planning:

It should be clear to the reader that the main feature of PRISMS is the MRP system. This feature is utilized in several modules. The blender schedule is the Master Production Schedule (MPS). Explosion and time-phazing of the MPS, taking into account the bills of material and the manufacturing lead time, determine the MRP records for blend components, reactor products and raw materials.

The system uses different "time buckets", months for the three-monthly planning and for the short term scheduling the system makes use of the daily "time buckets". The daily "time buckets" can be further detailed because of the necessity to include cycle times which are short. This refinement is used for calculation purposes.

Another important issue is the capacity planning. The system permits the user to diagnose capacity problems, but the scheduler must himself adjust the proposed reactor schedule which is obtained after the MRP explosion of the blender schedule (MPS). This step is necessary as there is no heuristic included to solve the capacity problems and to reflect any independent demand for reactor products. PRISMS is not geared to automatically change schedules such that capacity and loading problems are avoided.

The interactive deterministic simulator for scheduling the plant operations has following main characteristics:

- The user has to input the blender schedule and, if needed, to adjust the reactor schedule. The system evaluates the consequences of the proposed schedules on feed and finished product inventory levels. In other words, the user does the thinking and the system the computing.

- The system contains a case management for saving and retrieving solutions (i.e. complete operation schedules). It is possible to restore and change old cases in the light of new events (interchange of reactor runs, accidental shutdown of units, etc...)

- The system is completely data driven, i.e. the physical structure of the plant (blenders, reactors, inventory facilities, etc...) is defined by the user and not hard-coded in the system. The system is a general framework for scheduling problems at plants with two-level production processes. This design makes it possible for the user to easily adjust the system for changes in plant structure.

Using casebank facilities, the user can define and redefine different alternative schedules for the blenders and reactors. The system then computes and displays the material resources and inventory projections for all components and raw material over time. By checking the feasibility and by comparing the results for the different alternative schedules, the user can then choose that alternative which seems the best to him. The system is not designed to handle any cost comparisons between two alternatives.

The authors are aware of the existence of a large number of optimal and heuristic solution methods for determining economic manufacturing quantities for multi-item production environments (2). These algorithms range from the easy to understand Common Cycle approach to the more complex dynamic programming models. Unfortunately all these approaches share the lack of a standardized feasibility test and a lack of a standardized "infeasibility escape procedure". The feasibility aspect is extremely important because the items share a common machine (blenders or reactors). The real-life complexity is generally known to be the major handicap for the practical use of the models found in literature. Nevertheless, the lessons to be learned from these approaches are helpful for the scheduler.

IV. PRISMS AND MICROCOMPUTERS

Recently, an explosive growth of usage of microcomputers, such as the Apple, the Radio Shack and IBM PC, has been encountered for materials management and distribution operations. Good off-the-shelf software packages are not yet available, but numerous consultants claim that they have software packages for micros that can be tailored for specific applications (8).

Besides the IBM debut and the enhanced computing power that 16-32 bit architectures provide, we also have seen a steady reduction in massstorage cost. Microcomputers initially utilized "floppy disks" with capacities of about 250-320KB (characters). They expanded up to several millions of characters usage, using the hard disk devices.

More than anything else, this low cost mass storage is what has made Manufacturing Resource Planning systems possible on the micro. Speed is extremely important but without adequate mass storage, you simply cannot retain enough information to do MRP.

In addition, powerful operating systems (CP/M, MS/DOS, UNIX, OASIS etc..) and development tools such as data base managers and language processors (BASIC, PASCAL) are now available for micros. Complete database management packages are available from various vendors including MDBS from Micro Data Base Systems and dBASE II from Ashton-Tate. They all offer new opportunities for application software developers.

Based upon the functional specifications, Essochem Europe Inc. first built a prototype for PRISMS, written in CP/M MBASIC on an Apple II+. Programming in MBASIC was done intensively. All the screens described in the functional specifications were developed using a general fullscreen package developed in CP/M MBASIC (6).

One of the main shortcomings of the prototype version was the low computation speed which was due to:

- the programming language used (MBASIC);
- the use of several floppy disks to store an enormous amount of data;
- the linked list structure used to store the bills of material, which required many disk read/write operations during MRP calculations.

Another problem with using MBASIC was the database housekeeping capabilities. These had to be written from scratch.

Therefore, the final development of PRISMS was totally redesigned based on the early experiences (3):

- an IBM PC (512K3) with a Tallgrass hard disk (12MB) and tape backup was chosen as hardware.
- a database package, dBASE II was chosen to handle file management.
- MBASIC was still used as programming language for the calculation routines. However, these MBASIC programs are compiled which speeds up calculation up to four times.
- a matrix algorithm has been used for the MRP calculation (5).
- the linked list structure has been replaced by a matrix stockage which was possible with the inclusion of a hard disk.

In addition to the need for speeding up of PRISMS, the software choice also has been redone to facilitate the development. PRISMS consists of dBASE II modules for all database management and transaction systems. MBASIC is used for the deblend/dereact calculations, the MRP logic, the monthly planning and the daily/weekly scheduling. dBASE II provides fullscreen data input and database management capabilities and enables the development of new reports on the database.

It is also easier for systems to maintain dBASE II command files instead of MBASIC programs. The whole system has been written in about 1000 programming hours (1MB of programs).

It is interesting to note that the MBASIC programming language is used to develop calculation routines. MBASIC is limited to run in 64KB memory. The strategy applied in developing an MRP system with such a limited core is the use of segments.
The memory of the IBM PC used was upgraded to 512KB. Each segment covers 64KB and contains a part of the complete matrix structure needed to deblend and dereact demand requirements.
One matrix basically contains the quantities of reactor products and blend components needed to produce one unit of finished product. Another matrix contains the quantities needed of raw materials to produce one unit of a reactor product.

The PRISMS software is transportable. It can be run on a variety of hardware with MS/DOS as operating system, dBASE II as database management software and MBASIC as programming language.

Since PRISMS is implemented on a microcomputer, it enjoys the main advantages of a microcomputer system :

- relatively low equipment costs, operating costs and maintenance costs.
- easy to implement and to start up.
- minimal space requirements, so that it can be placed where it belongs: in the scheduler's office.

Two disadvantages should be remembered: PRISMS is a single user system and up to now no interfaces are built with other systems.

V. SUMMARY

During the last years, the enlarged memory capacities of most existing microcomputer systems lead to the investigation of their possible use for solving business problems in a more user-friendly manner.

Using such a microcomputer approach for the Essochem Paramins Reporting and Information System for Manufacturing Resource Planning and Scheduling resulted in a menu-driven system that provides optimal access possibilities to any part of the system and easy fullscreen updating of the database and the schedules. PRISMS is a general production framework which enables future extensions with minor effort. PRISMS consists of a large plant database, a transaction system for both order and inventory tracking and various calculation routines such as inventory projector, a deblend/dereact calculator, and an MRP calculator.

Regarding the software possibilities for implementing PRISMS on a microcomputer, we think that the nature of the system and the requirements of fullscreen updating, limit the appropriate software tools to a database management system such as dBASE II and the MBASIC language for the calculation requirements.
That combination seems to be the most effective software to develop such a weekly production scheduling and monthly production planning tool.

BIBLIOGRAPHY

1. DEVIS M., Design and Development of a Microcomputer Scheduling Model for Planning the Vistalon production in Essochem, K.U.L., M.B.A. Thesis, 1982.

2. ELMAGHRABY S., The Economic Lot Scheduling Problem : Review and Extensions, Management Science, Vol.24, no.6, Feb. 1978, pp 587-598.

3. EVENS J., HERSSENS E., REUSENS L., Design and Development of PRISMS, Project for Course Computer Applications in Management, K.U.L., 1983.

4. KOCHALKA T., MRP in Process Industry - Why Wait?, Production and Inventory Management, 4th Quarter 1978, pp 17-22.

5. LOCKYER K.G. & OAKLAND, J.S., Management Tools in the Manufacture of Chemicals, Material Requirements Planning,Chemistry and Industry, 16 August 1980, pp 642-645.

6. MATTHIJS F., Deisgn of PRISMS, Paramins Reporting and Information System for MRP and Scheduling in Essochem Europe, M.B.A. Thesis, K.U.L., 1982

7. NELSON N., MRP and Inventory and Production Control in Process Industries, Production and Inventory Management, 4th Quarter 1983, pp. 15-22

8. PENNENTE E., LEVY T., MRP on Microcomputers, Production and Inventory Management Review and APICS News, May 1982.

9. VAN DEN WIJNGAERT F., Exploration Study of PRISMS, Essochem Europe, Internal Report, 1981.